WiBAR: Wideband Autocorrelation Radiometry for Measuring Snow and Ice Accumulation

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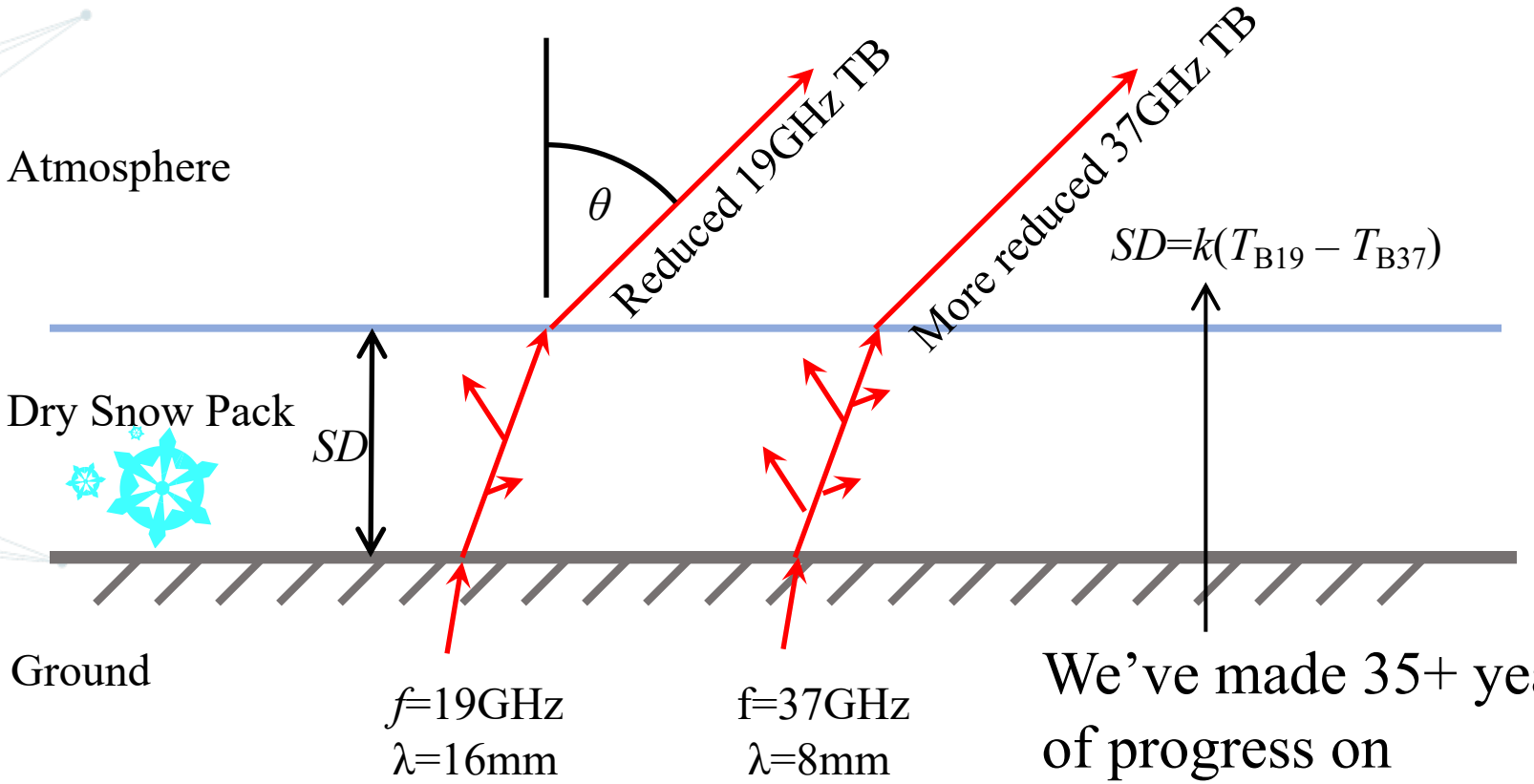
How much water is stored in the seasonal snow pack?

- Billions of people around the world depend on snowmelt for their water
- We don’t yet have a reliable way to measure the storage of water in the snow pack globally
- The remote sensing community has not yet settled on the optimal combination of approaches for this problem (eg. NASA SnowEx)
- WiBAR is another tool:
  - -microwave, so all-weather
  - -passive, so low power, thus low cost
  - -deterministic, so no algorithm calibration

Why a new way to measure snow?

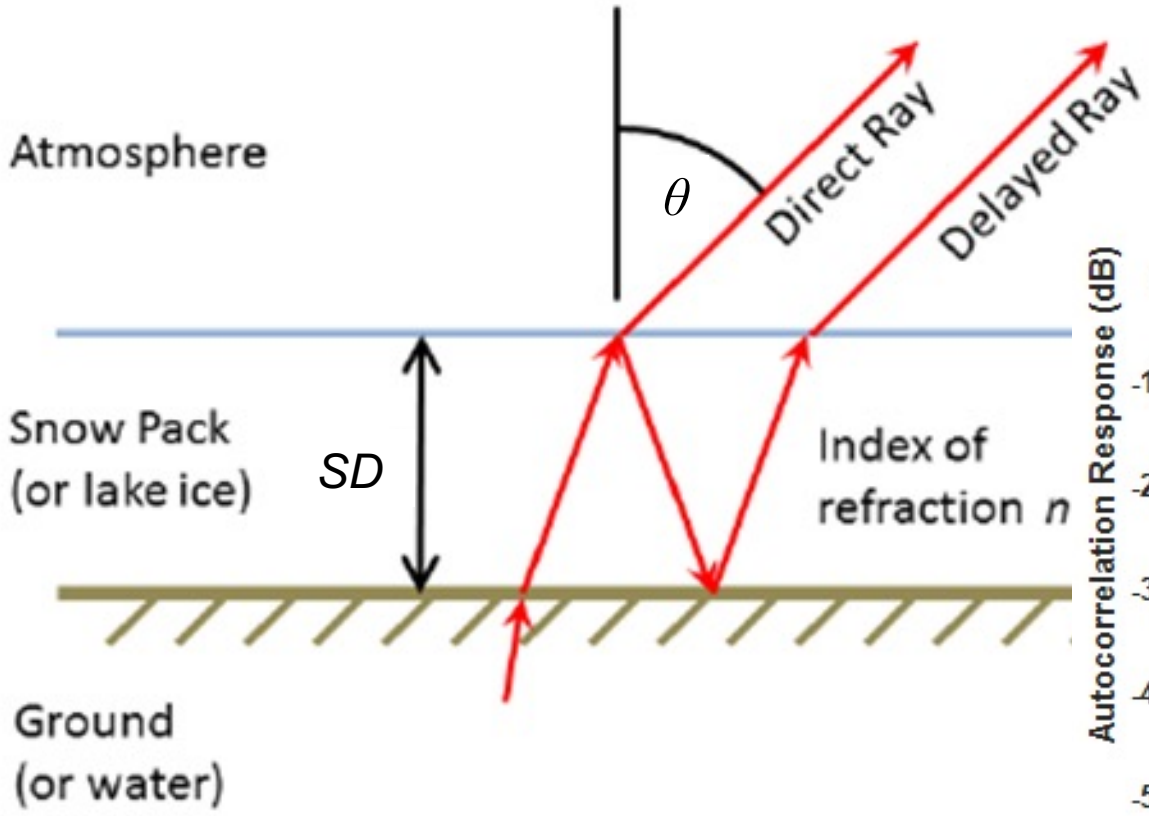
Today's operational method: differential scatter darkening

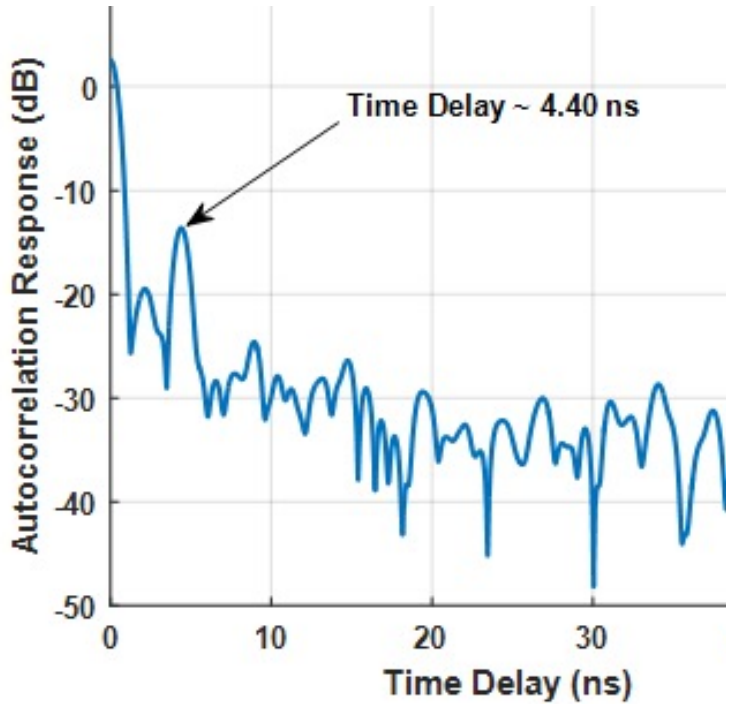


We've made 35+ years of progress on calibrating the algorithm

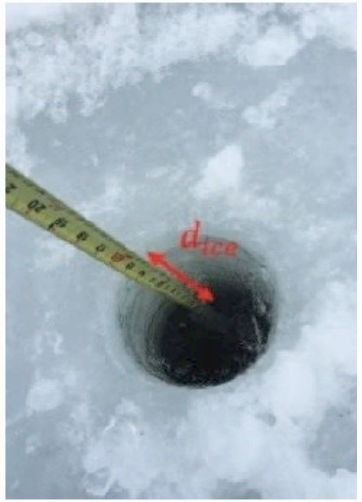
WiBAR measures Planck coherency

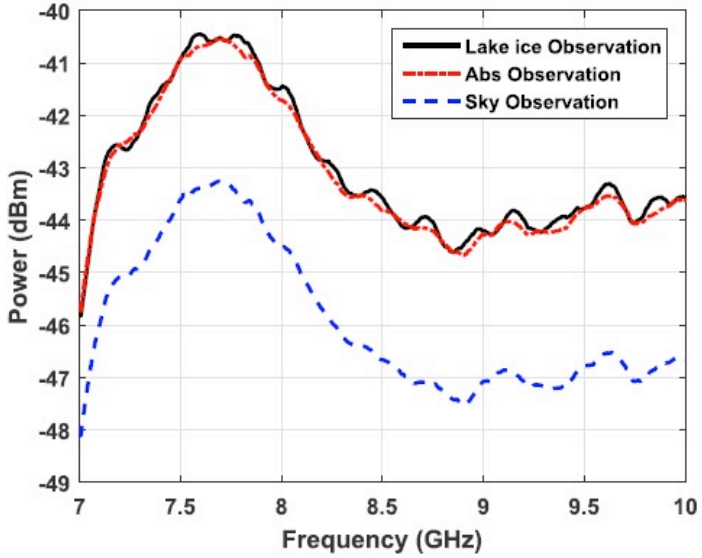
$$\tau_{delay} = 2\,(SD/c)\,(n^2 - \sin^2\theta)^{1/2}$$

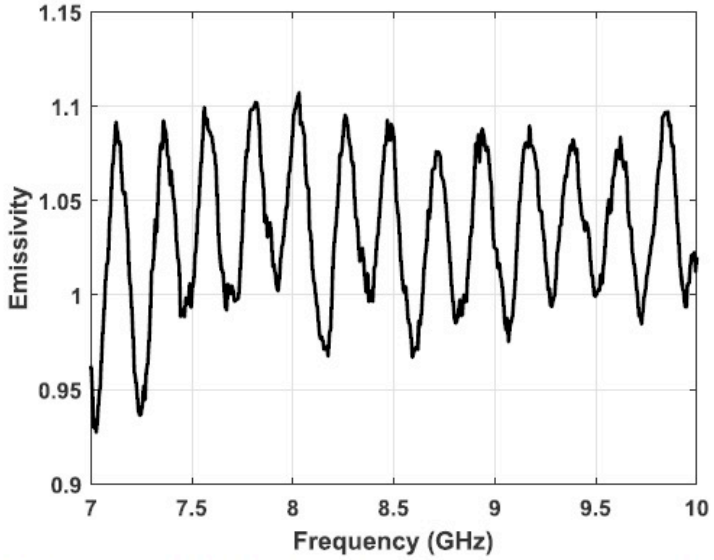


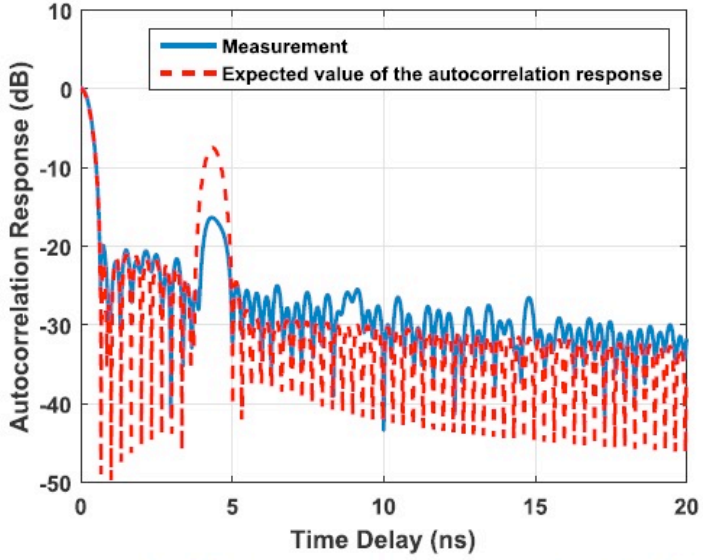


WiBAR can measure ice thickness …



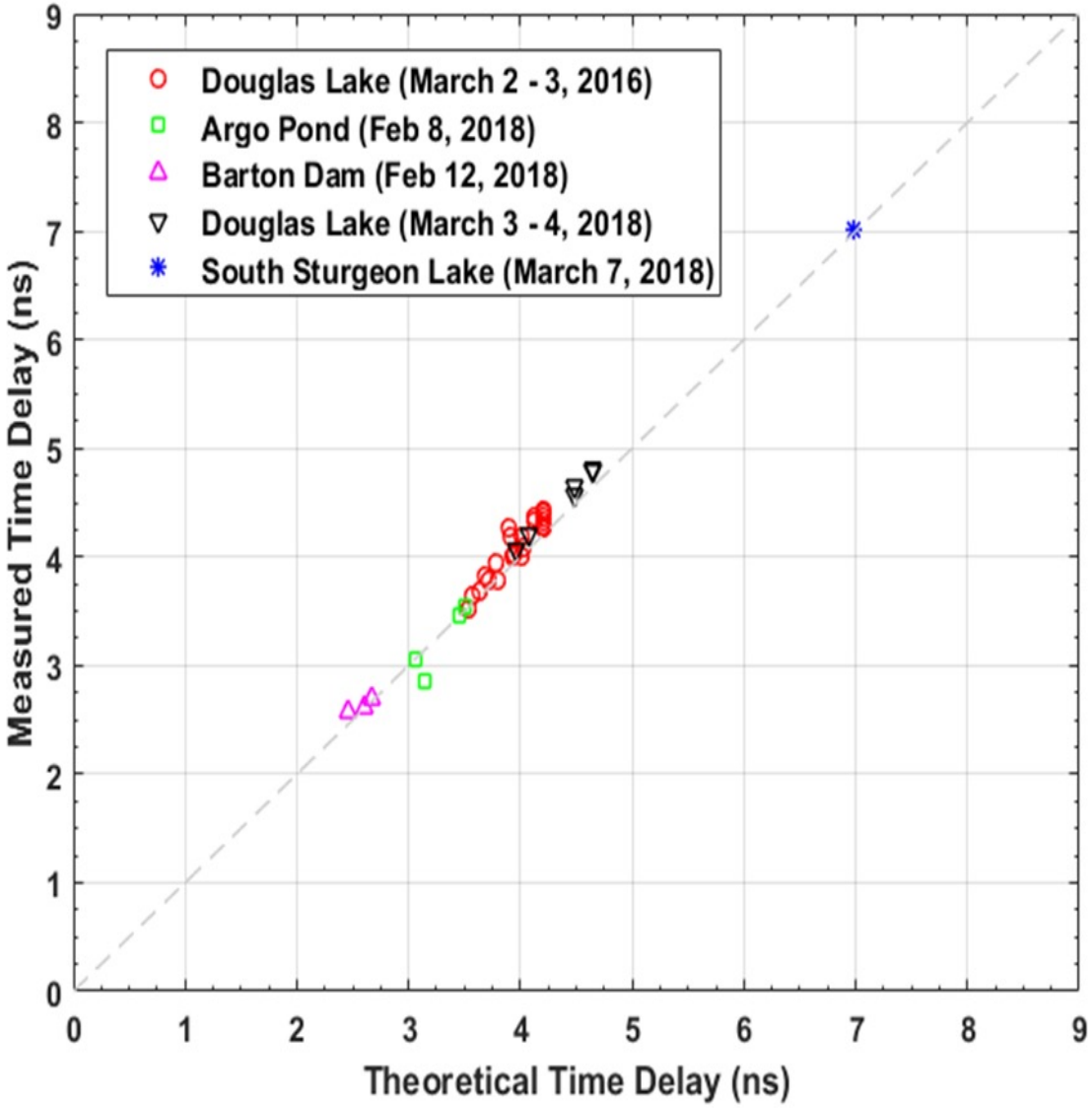




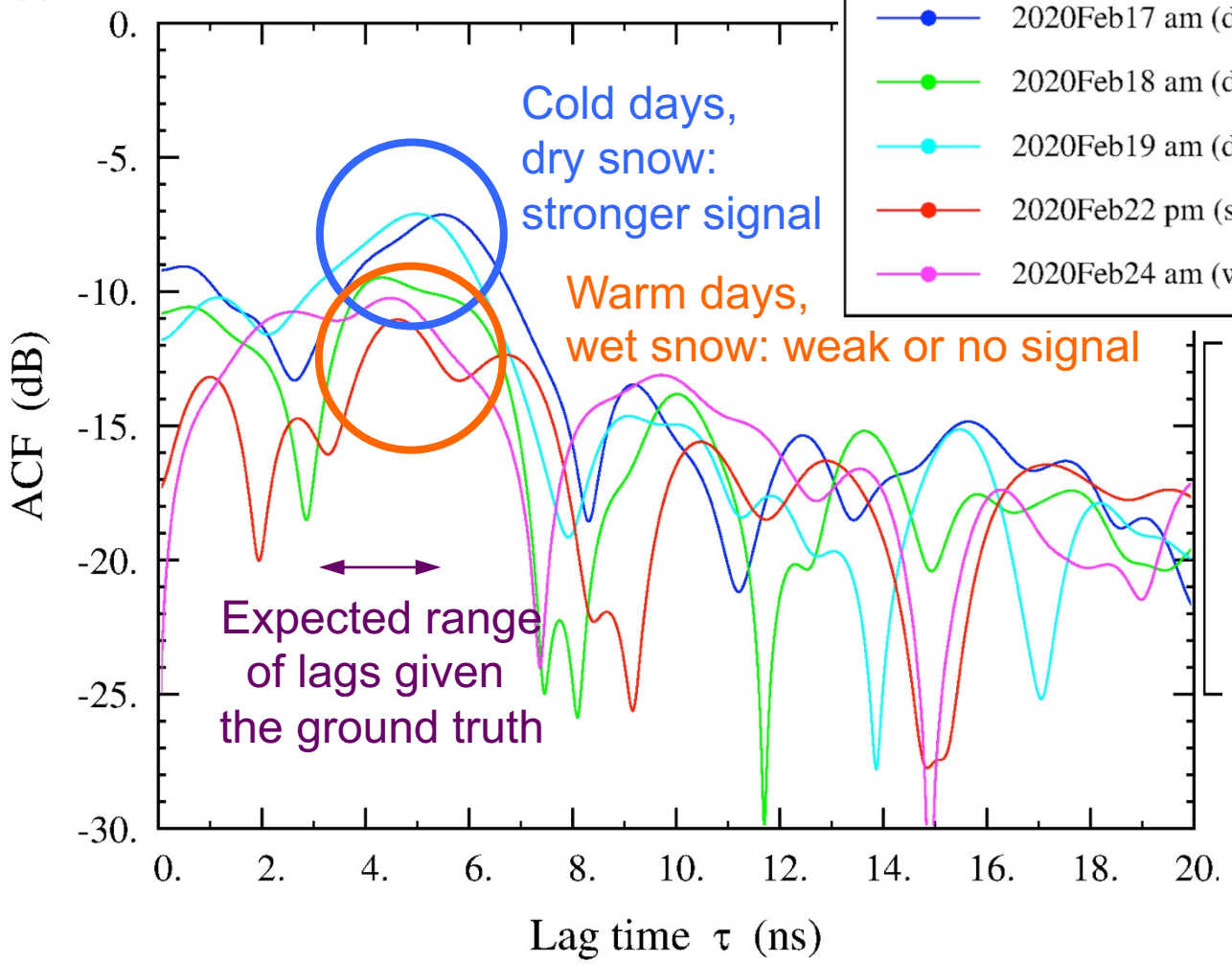


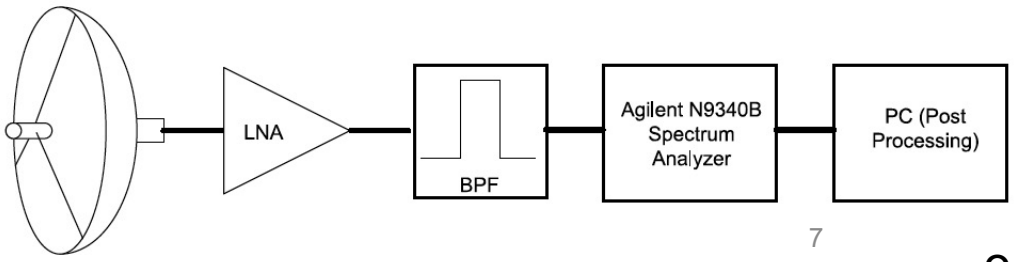
… accurately

- X-band FD-WiBAR
- Ice thickness measurements
- Bare ice and with thin snow cover
- Theoretical derived from ground truth (ice thickness & incidence angle)



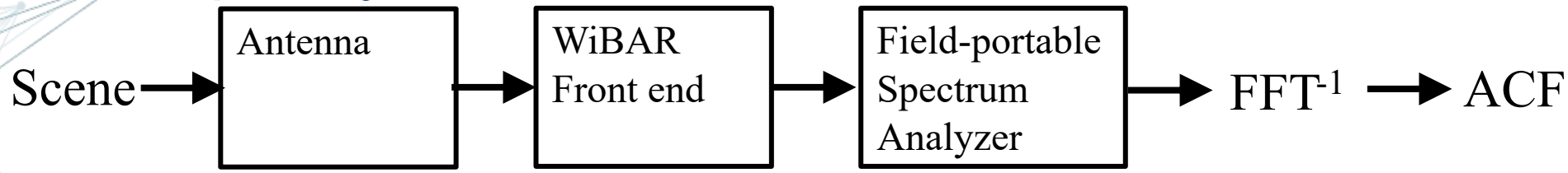
Evidence of coherent emission from snow



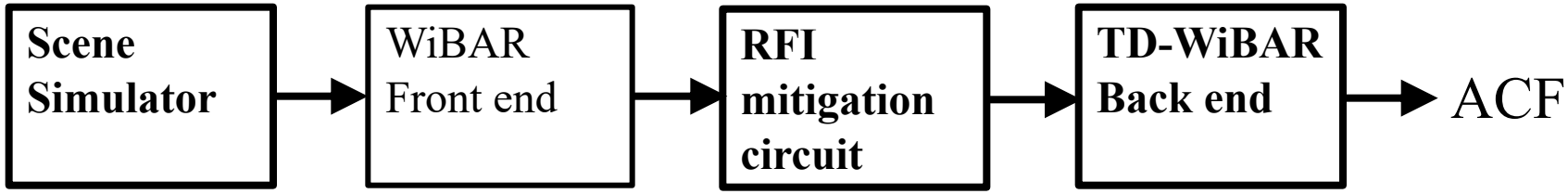


A faster architecture: TD-WiBAR

- Our initial studies relied on a “rapid implementation”, or “frequency domain” WiBAR:

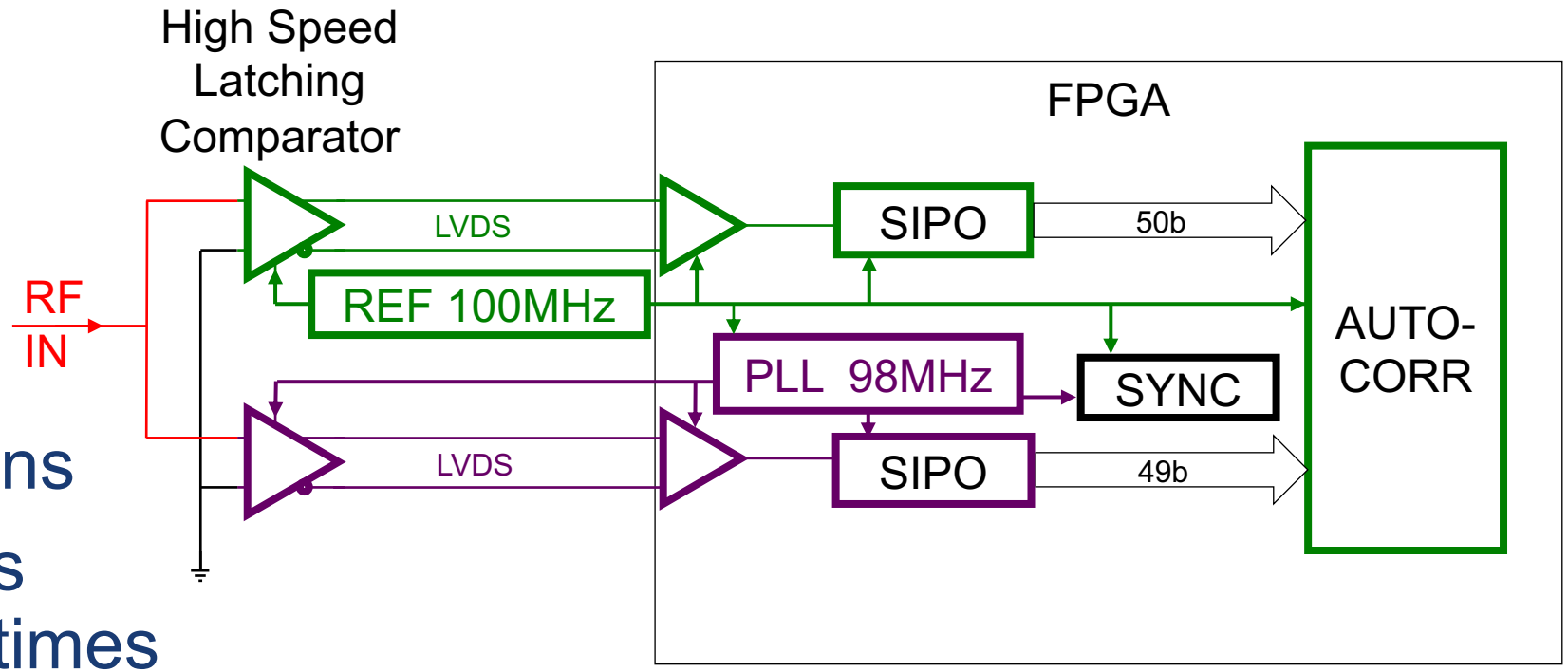


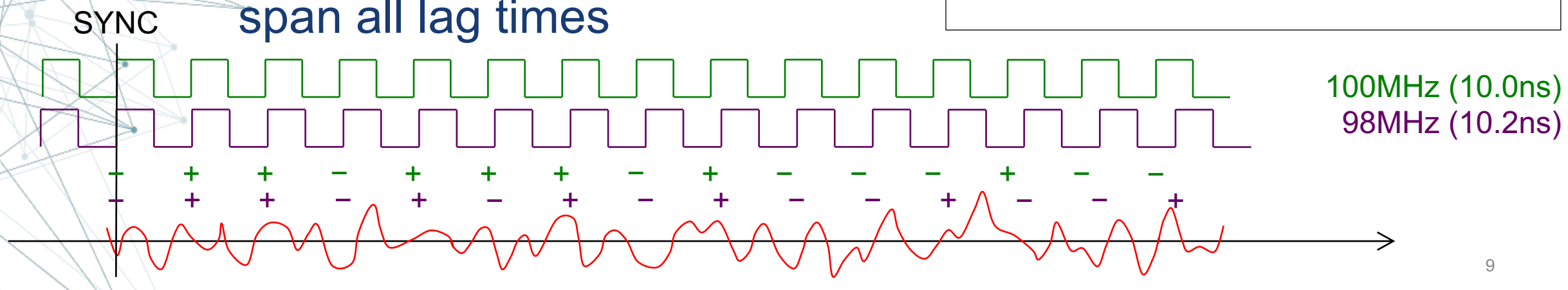
- but instantaneous bandwidth is small, so measurements take a long time (minutes)
- An alternative, “time domain” architecture that looks at the full spectrum at once, and is much faster (thanks ESTO!):



One bit autocorrelator w/ 0.2 ns resolution

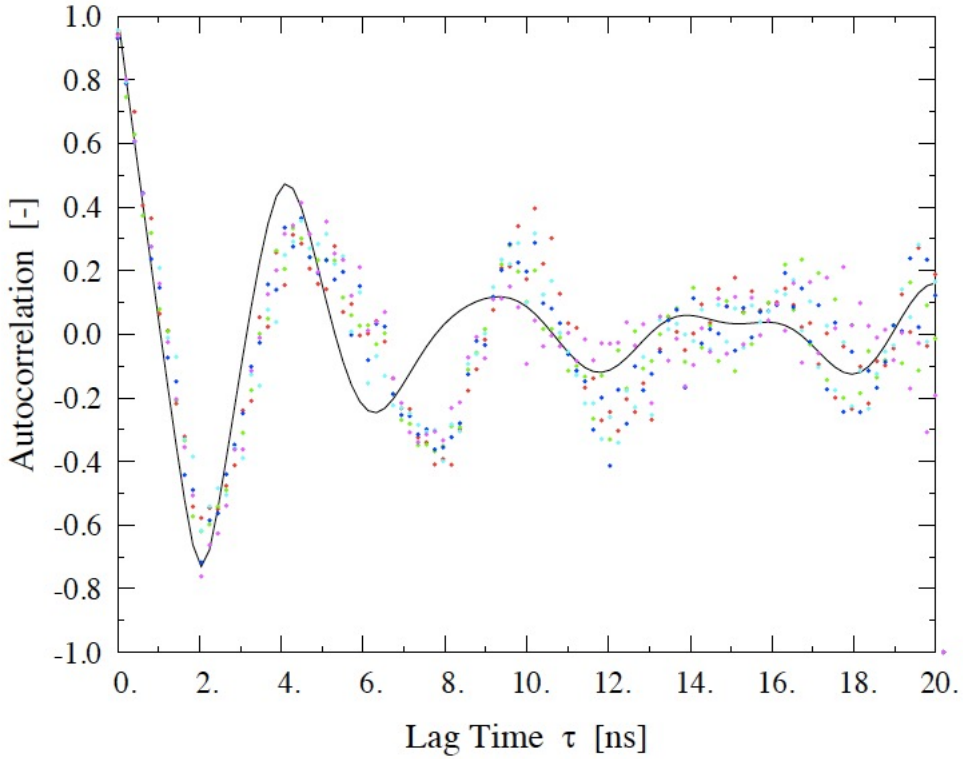
- Sub-Nyquist sampling w/ two clocks
- Clock periods differ by 0.2 ns
- Sample pairs span all lag times

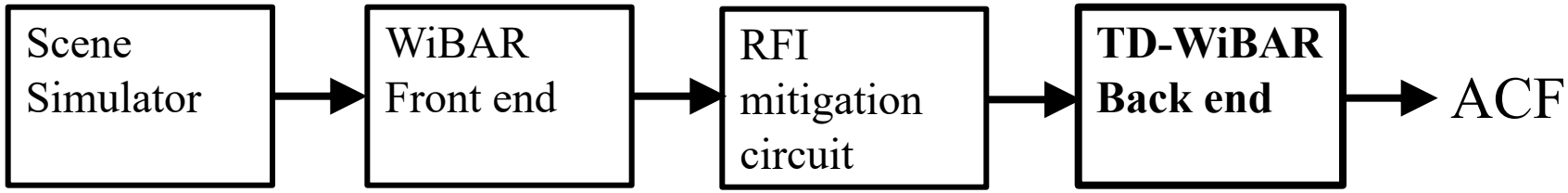




Autocorrelator has a low-pass response

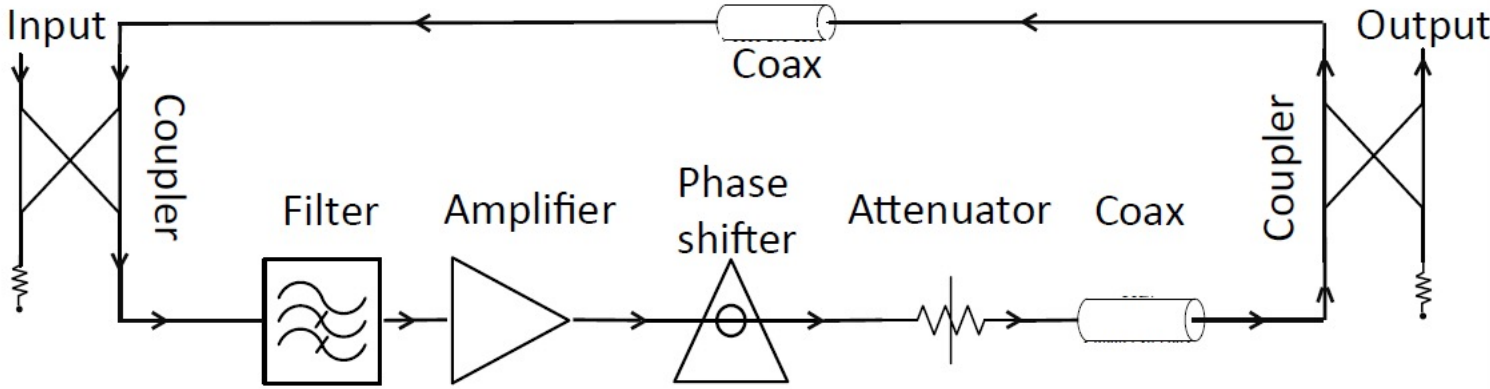
- Output from the one-bit correlator
  - dots are data
- Input is 5 tones on an arbitrary waveform generator
  - curve is the expectation



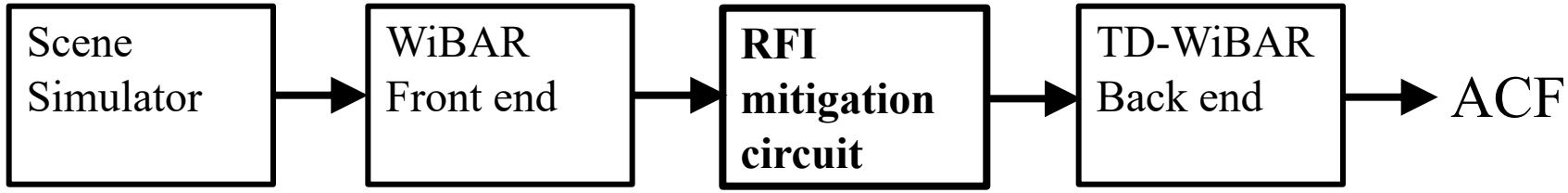


A tunable comb filter for RFI mitigation

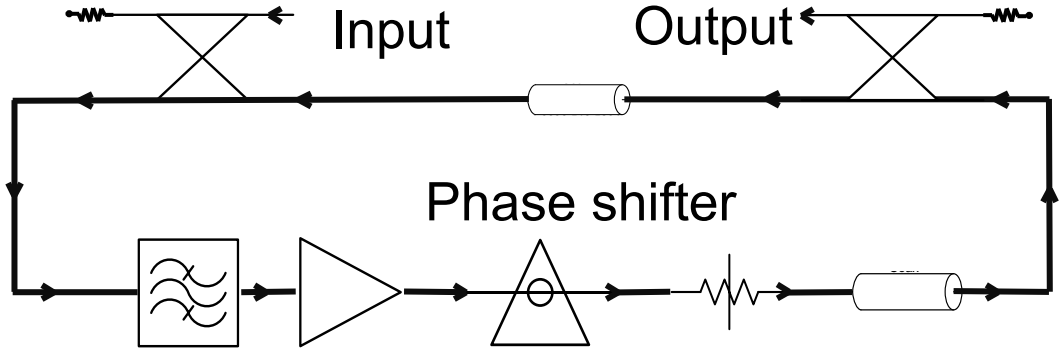
- WiBAR needs a wide frequency range, but not much bandwidth



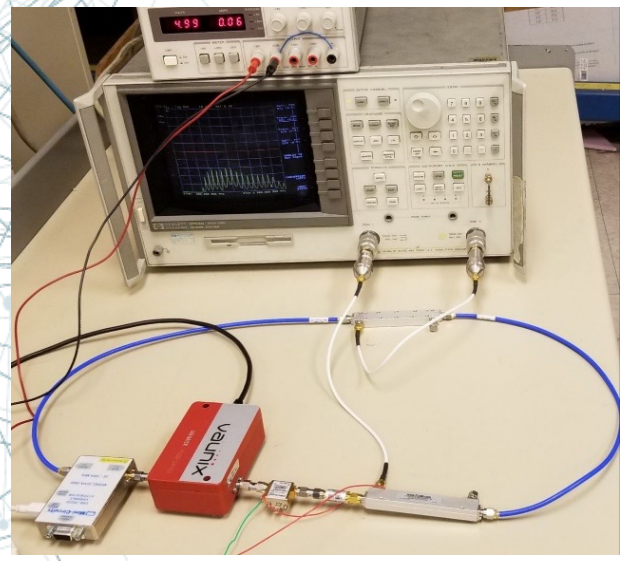
Microwave comb filter ←→ Optical Fabry-Perot interferometer (FPI)
Two directional couplers ←→ Two metal film reflectors in FPI
Transmission line ←→ Spacing between two reflectors
Phase shifting ←→ Changing distance b/t reflectors



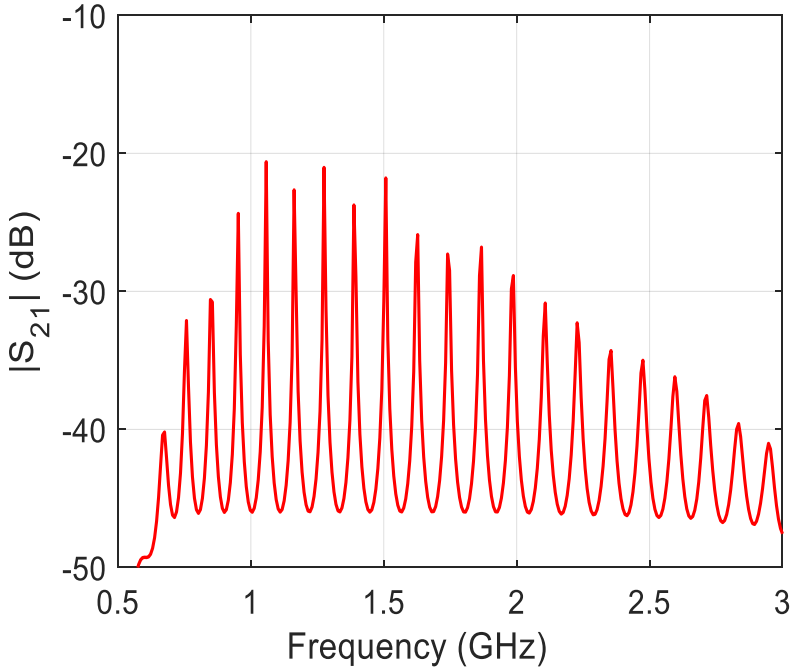
Comb Filter Measurement Results



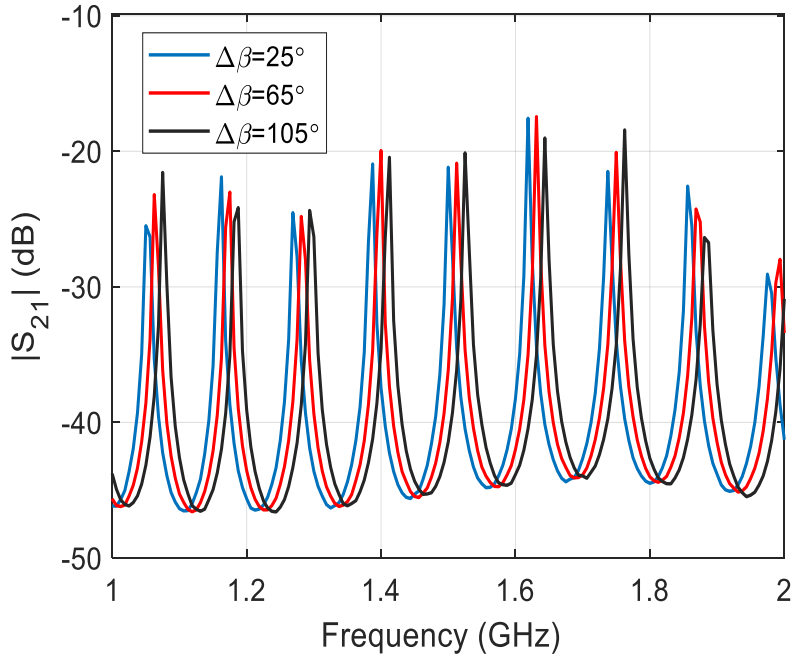
Measurement setup



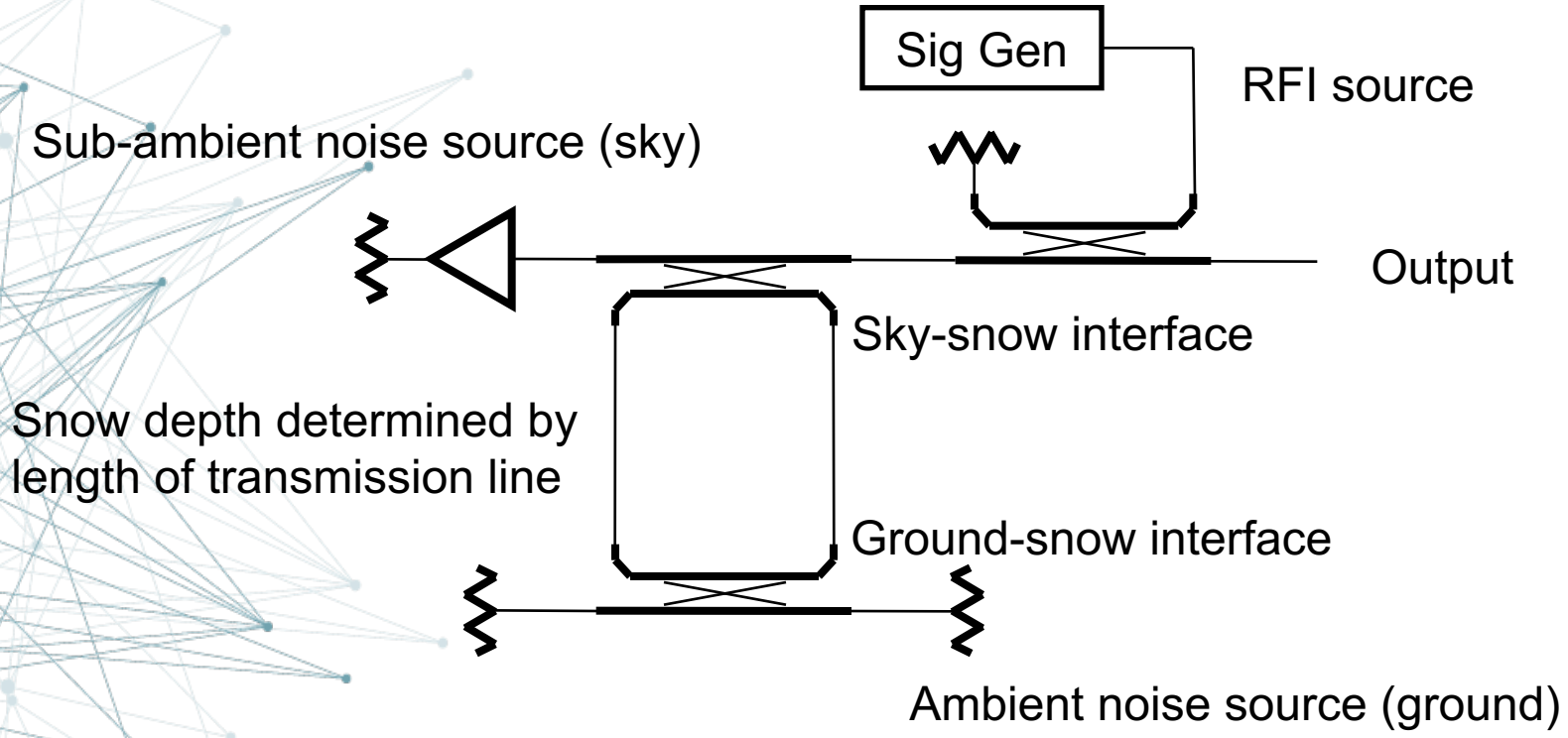
Comb Filter Response

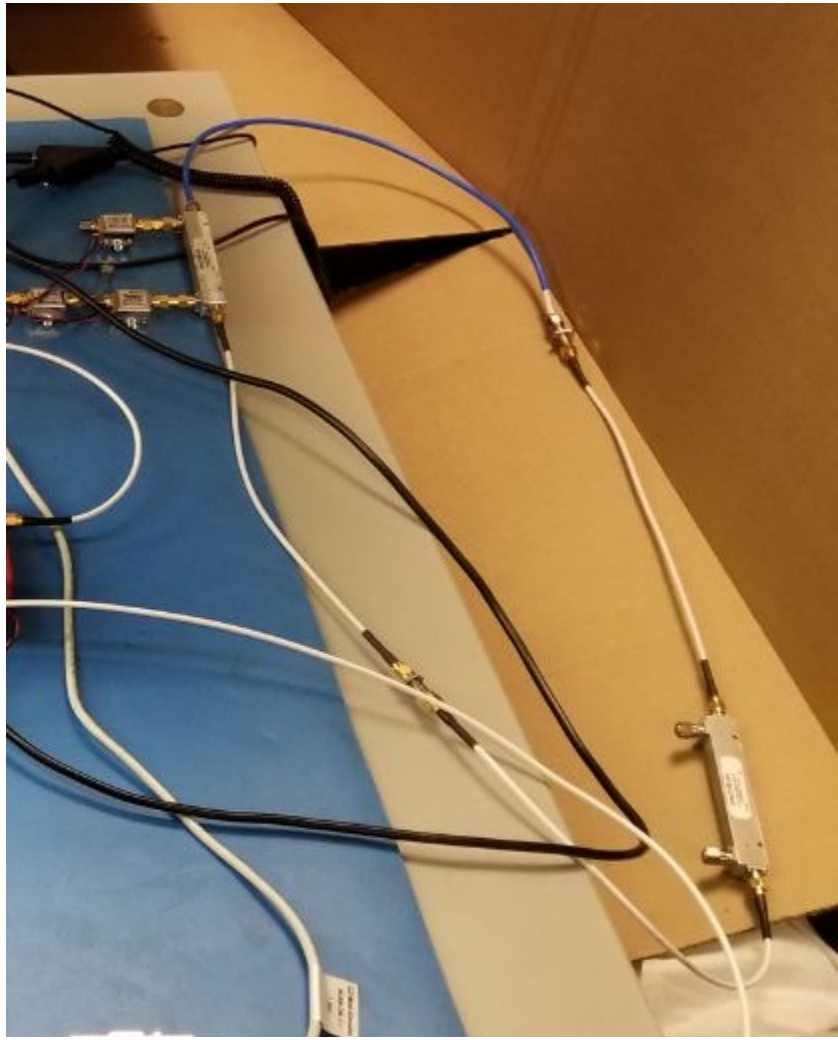


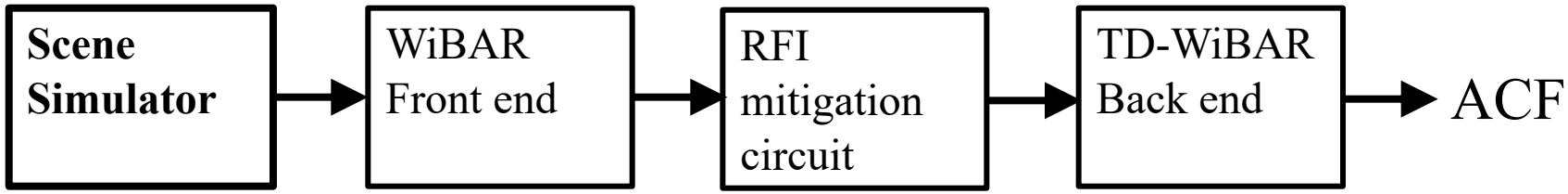
Effect of phase adjustment



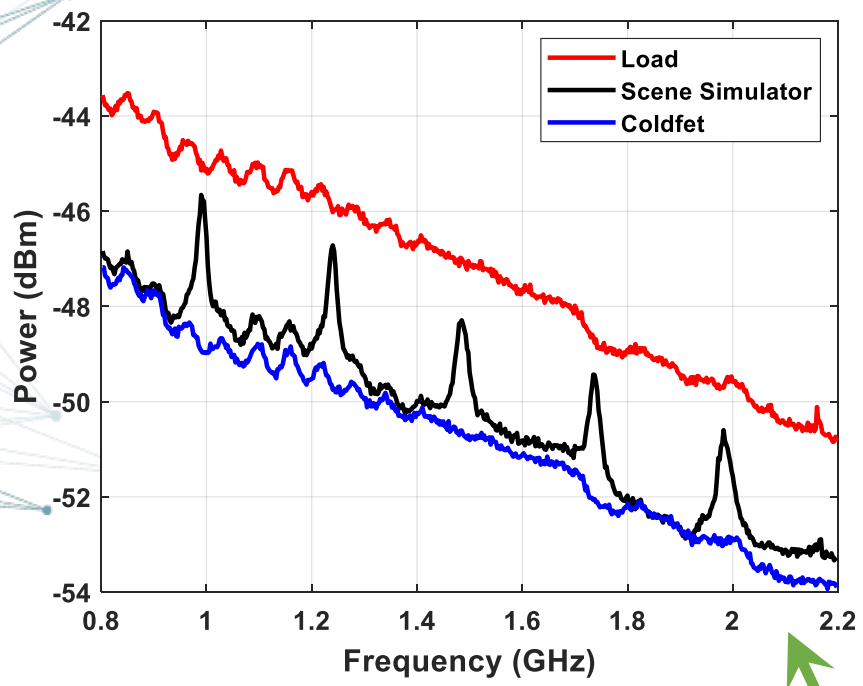
WiBAR Scene simulator

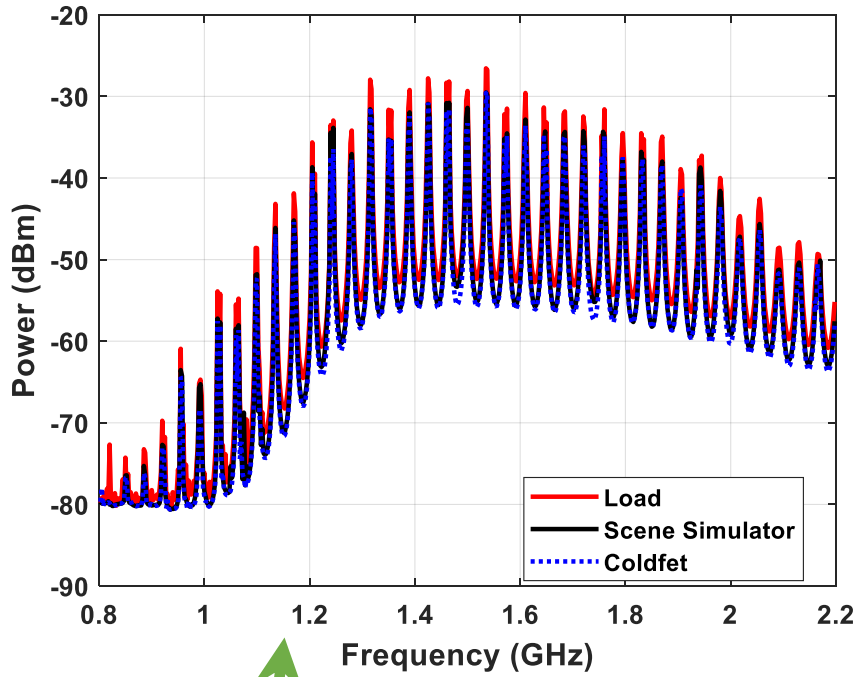


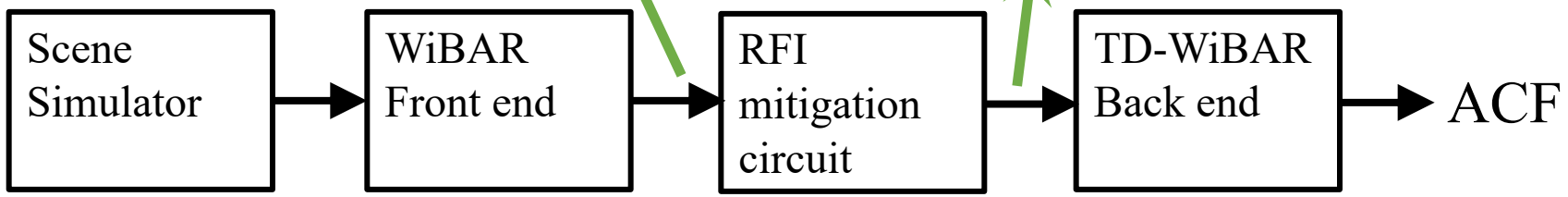




A new WiBAR calibration is needed

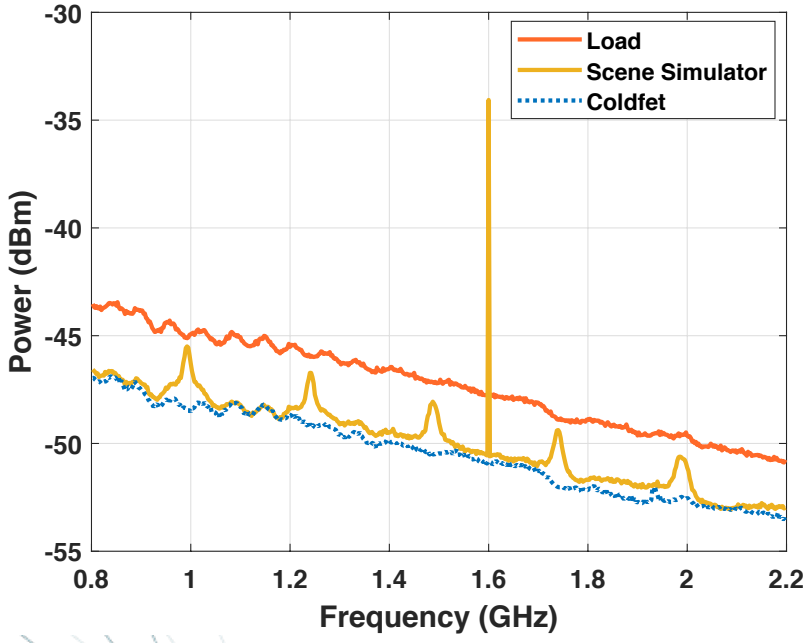


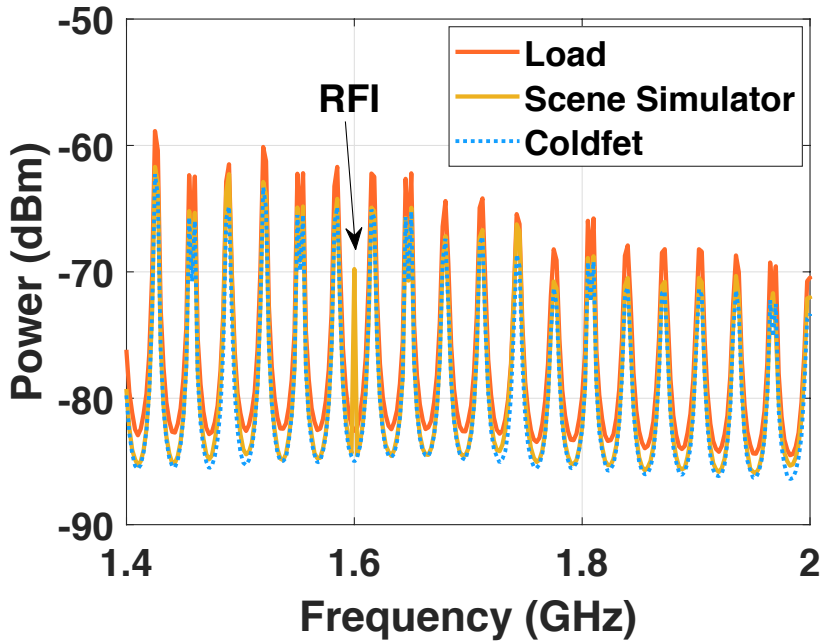


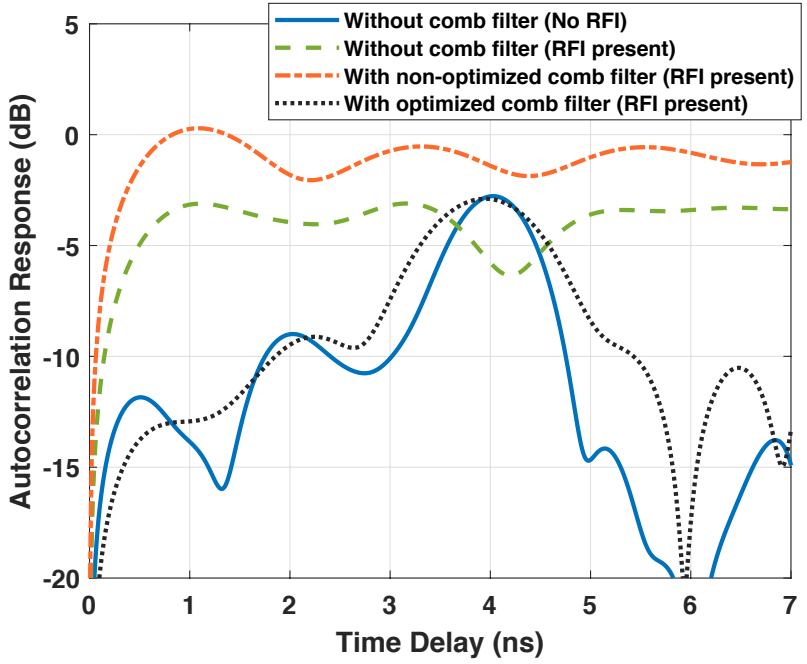


A TD-WiBAR calibration can remove RFI

- Adjust comb filter phase to minimize output power
- Bonus: new calibration algorithm also removes zero-lag peak and its sidelobes







Contributions

- Novel microwave receiver architecture for passive measurement of snow and ice accumulation that is sensitive to its macroscopic, not microscopic, properties

Next Steps

- Final integration and test of rapid acquisition hardware
- Validate RFI mitigation effectiveness
- Develop reduced SWAP receiver
- Go airborne, produce images & attempt disaggregation

Wideband Autocorrelation Radiometry

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